

Kong, S.C., Ogata, H., Arnseth, H.C., Chan, C.K.K., Hirashima, T., Klett, F., Lee, J.H.M., Liu, C.C., Looi, C.K., Milrad, M., Mitrovic, A., Nakabayashi, K., Wong, S.L., Yang, S.J.H. (eds.) (2009). *Proceedings of the 17th International Conference on Computers in Education [CDROM]*. Hong Kong: Asia-Pacific Society for Computers in Education.

# Learning Effectiveness in a Desktop Virtual Reality-Based Learning Environment

Elinda Ai-Lim LEE<sup>a,b</sup>, Kok Wai WONG<sup>a</sup>, Chun Che FUNG<sup>a</sup>

<sup>a</sup>*School of Information Technology, Murdoch University, Australia*

<sup>b</sup>*FSKM, Mara University of Technology Sarawak Branch, Malaysia*

elinda.lee@murdoch.edu.au

elinda@sarawak.uitm.edu.my

**Abstract:** The purpose of this study was to compare the effectiveness of a desktop virtual reality-based learning environment with a conventional classroom learning practice. The learning effectiveness was measured through academic performance, perceived learning and satisfaction. A quasi pretest-posttest experimental design was employed for this study. A total of 431 students participated in this study; however, only 370 samples could be analyzed due to incomplete instruments answered. The students were randomly assigned to either experimental or control groups based on intact classes. There was a significant difference in the academic performance, perceived learning and satisfaction between the two groups. It was concluded that the desktop virtual reality instructional program positively affects the students' academic achievement and their perceived learning quality and satisfaction.

**Keywords:** desktop virtual reality, academic performance, perceived learning, satisfaction

## Introduction

Recently, there has been an increasing enthusiasm of using desktop Virtual Reality (VR) for educational purposes because of its ability to provide real time visualization and interaction within a virtual world that closely resembles a real world [1]. Moreover, a rapid and drastic fall in prices and a huge leap and improvement in the processing power of personal computer have aggravated the use of desktop virtual reality in schools and colleges. In desktop VR, which is also known as non immersive VR, the interactive three-dimensional (3-D) computer generated program in a multimedia environment is presented on a conventional personal computer and is usually explored using keyboard, mouse, wand, joystick or touch screen [2, 3]. The distinct feature of VR is the sense of presence or "being there" when interacting with the VR-based learning systems. Though desktop VR is considered less immersive; however, Dalgarno, Hedberg & Harper [4] argue that "*the sense of presence or immersion in a virtual environment is induced by the representational fidelity and the high degree of interaction and control of user, rather than just a unique attribute of the environment.*" Desktop VR has been widely used as an educational tool because of its feasibility and cost effectiveness [2]. According to Youngbult [5], the non immersive technology is much more mature and widely used in many different application areas as compared with the immersive technology. Immersive VR environments are presented on multiple, room-size screen or through head-mounted display unit [2-4]. The need for expensive peripheral devices and high-end computer systems has somehow restricted its use in schools or colleges.

VR has become well suited and a powerful medium for learning in school [6], especially for science and mathematics which involve the study of natural phenomena and abstract concepts. Research has shown an encouraging array of positive learning outcomes in examining desktop VR technology to support learning. Findings include positive effect on students' learning of geometric topics [7], better learning in geosciences [8], and useful training system for astronaut 3D navigation [9]. Apart from these, research findings have also shown that learners enjoy their VR educational experience and see the potential of VR in instruction [10].

VR is hypothesized to be an excellent educational tool because it offers the opportunity to visualize, explore, manipulate and interact with objects within a computer generated environment [11], which allows for discovery and self-paced learning. A more student-centred approach of instruction is possible with the use of VR. Nevertheless, VR is just an educational tool which can be used to support learning and it might not work for all kinds of learning. In spite of the positive findings of some research, it would be premature to make broad recommendations regarding the use of VR as a curriculum enhancement [3], and it should not be used indiscriminately in any educational program [12]. Furthermore, there have been very few studies that compare the effectiveness of VR against non VR teaching practices to support the use of VR in learning [5, 13]. Additionally, research has shown that a teacher-centred method is more effective than the student-centred mechanism [14, 15]. Thus, these motivate the objectives of this study.

## 1. Research Objectives

The purpose of this research was to compare the learning effectiveness of a desktop VR-based learning environment with a conventional classroom learning practice. A VR software program, V-Frog, was used as the VR learning material. Both groups of students underwent a similar lesson on frog anatomy but through different means. As shown by research, VR not only influences the cognitive outcomes but also the affective domain. Thus, this study measured the learning effectiveness in terms of academic performance, perceived learning and satisfaction. Academic performance was measured through a summative assessment while perceived learning and satisfaction were measured subjectively through a questionnaire. The following objectives guided the proposed study:

1. To determine the effects of a desktop VR-based learning environment on students' academic performance
2. To determine the effects of a desktop VR-based learning environment on students' perceived learning
3. To determine the effects of a desktop VR-based learning environment on students' perceived satisfaction.

## 2. Research Hypotheses

In pursuance of the research purpose and objectives, the following three hypotheses were formulated for testing:

H<sub>01</sub>: There is no significant difference in the academic performance between students in the VR group and Non VR group

H<sub>02</sub>: There is no significant difference in the perceived learning between students in the VR group and Non VR group

H<sub>03</sub>: There is no significant difference in the perceived satisfaction between students in the VR group and Non VR group

The findings of this study will contribute to our understanding of the learning outcomes of a desktop VR-based learning environment and provide empirical evidence of the merit of desktop VR-based learning to educators and policy makers.

### **3. Methodology**

#### *3.1 Research Design*

A two-group pretest-posttest experimental design was employed in this study. The permission from education department and school administrators, the willingness of teachers and students, and the computer system facilities in schools were all prerequisites required to execute this study. As the class organization could not be reorganized, a quasi-experimental research method was used to randomly assign the selected classes into experimental and control groups. Each group was given a pretest, posttest and questionnaire to answer.

#### *3.2 Population and Sample*

The population for this study was Form Four science students, aged between 15 and 17 years old of any co-education secondary schools that are well-equipped with multimedia computer laboratories in a city of East Malaysia. Form Four science students were chosen because they were within the targeted population as they have started to learn biology in Form Four.

Four different co-education secondary schools were randomly selected (based on the simple random sampling technique) from the list of co-education secondary schools in the city. For each selected school, two to four intact classes were randomly chosen. These selected classes were then randomly assigned to either experimental or control groups.

#### *3.3 Instruments*

##### *3.3.1 Pretest and Posttest*

Both pretest and posttest were similar in content but the order of the questions was different to avoid the set response effect. The tests include questions regarding frog anatomy for the modules covered in this study. Content validity of these tests was determined by expert judgment. Three subject matter experts were requested to review the test questions and make a judgment about how well these items represent the intended content area. A pilot study was carried out in one co-education secondary school from the same city with forty seven randomly selected Form Four science students to obtain information that was useful to improve these tests. These included the item difficulty index, item discrimination index, and internal consistency measure. Six items were deleted in which five items were deleted due to poor discrimination and one was deleted as it had a low corrected item-total correlation ( $r = 0.010$ ). As a result, the final version of the pretest and posttest contains 32 items with an alpha coefficient of 0.846. The item difficulty index was ranging from 0.27 – 0.85 which was of moderate difficulty [16].

### 3.3.2 Satisfaction

Students' perceived satisfaction in a desktop VR-based learning environment was measured using seven items adapted from Chou & Liu [17]. The original instruments have eight items with an alpha coefficient of 0.8625. This seven-item instrument with a five-point Likert scale for measuring satisfaction has an alpha coefficient of 0.899.

### 3.3.3 Perceived Learning

Perceived learning refers to the learning quality experienced by the participants. Based on the instruments of [18-20], an eight-item instrument was developed to measure perceived learning on issue identification, and integration and generalization of the lesson material. A five-point Likert scale was used to measure perceived learning. The internal consistency of alpha coefficient for this instrument was 0.899.

Ideally, the Cronbach's alpha coefficient of a scale should be greater than 0.7 [21]. Thus, all instruments have a good level of internal validity as measured by the Cronbach's alpha.

## 3.4 Software

A desktop virtual reality program, V-Frog, was used to provide the virtual learning environment to students. This software was developed and supplied by Tactus Technologies, Inc., New York. This virtual reality-based dissection simulator was developed using virtual surgery technology. Students can have hands-on learning experience with V-Frog. They can cut, pull, probe, and examine a virtual specimen, as they would with a real frog. Thus, each dissection is different, reflecting the individual work of each student. Actions are repeatable and the content presentation is nonlinear. In each specimen window, there are viewpoint manipulation tools for students to rotate, slide and zoom the specimen. There is also a reset button to reset the position of the specimen. Additionally, in some specimen windows, dissection tools such as scalpel and tweezer for students to cut and peel the skin are provided. Moreover, there are also query tool that allows students to get information about a part of the specimen; magic wand tool that activates and brings parts of the specimen to life; and probe tool that examines an orifice in the specimen. Besides, a virtual endoscopy can be conducted with the endoscopic tool to explore the entire alimentary canal. There is also a V-Frog lab report to guide students through all the modules, highlighting key points and relationships. The existence of lab report icon on the screen indicates to students that information on the current screen can assist them to complete their lab report successfully.

## 3.5 Data Collection Procedures

Two weeks before the treatment, respondents from both experimental and control groups were given a pretest regarding frog anatomy. During the treatment, the experimental groups learned by using the VR software program whereas the control groups underwent a conventional classroom learning method with Power Point slides conducted by their biology teacher. Three modules were selected for this study: Internal Anatomy, Digestive System and Circulatory System. Just before the treatment, the experimental groups were given training on how to use the V-Frog software program. Immediately after the treatment, which took about 1.5 hours, the respondents were given the posttest and questionnaire to answer. The contents of the questionnaire involve background

information, perceived learning and satisfaction questions. A gap of two weeks between the pretest and the posttest was for the purpose of reducing the pretest sensitization threat.

## **4. Results**

### *4.1 Characteristics of Sample*

A total of 431 students participated in this experiment. However, out of these students, 61 of them did not fully complete all instruments, that is, they were either absent in the pretest or posttest during the day of testing or did not return the questionnaire. Hence, only 370 participants were taken into consideration in the analysis. The sample was 42.2% and 57.8% in males and females, respectively. The mean age of the participants was 15.68 years old.

### *4.2 Distribution of Learners*

The 370 participants were randomly divided into two groups based on their intact classes. Each group was assigned to one of the two learning modes. A total of 210 participants were in the VR group whereas 160 participants were in the Non VR group.

### *4.3 Homogeneity of Pretest*

Independent-samples t-test was conducted to determine if the participants in the two learning modes were homogeneous in terms of existing knowledge of the subject matter, which was measured by the pretest. Statistical tests were conducted at the  $\alpha = 0.05$  significance level. The result shows that there was no statistically significant difference in the pretest score between VR group ( $M = 43.14$ ,  $SD = 19.98$ ) and Non VR group [ $M=42.46$ ,  $SD = 18.82$ ,  $t(368) = 0.330$ ,  $p > 0.05$ ]. It is thus inferred that both groups were equal in their prior knowledge on the subject matter.

### *4.4 Testing of Hypotheses*

Independent-samples t-test was used to analyze the data. Before t-test was conducted, the assumptions for this test were performed and this test was found to be appropriate for employment. Statistical tests were conducted at the  $\alpha = 0.05$  significance level.

#### *4.4.1 Testing of $H_{01}$*

The statistical results rejected the null hypothesis ( $p < 0.05$ ). There was a significant difference in the posttest score for VR Group ( $M = 65.51$ ,  $SD = 15.68$ ) and Non VR group [ $M = 60.56$ ,  $SD = 20.88$ ;  $t(284.863) = 2.506$ ,  $p = 0.013$ ]. (see Table 1.) Students in the VR group scored higher in the posttest than students in the Non VR group. However, the magnitude of the differences in the means was small (eta squared = 0.02). (see Table 1.) This interpretation was based on the guidelines proposed by Cohen [22]: 0.01 = small effect, 0.06 = moderate effect, and 0.14 = large effect.

#### *4.4.2 Testing of $H_{02}$*

The statistical results rejected the null hypothesis ( $p < 0.05$ ). There was a significant difference in perceived learning for VR group ( $M = 3.94$ ,  $SD = 0.53$ ) and Non VR group [ $M = 3.30$ ,  $SD = 0.49$ ;  $t(368) = 11.844$ ,  $p < 0.0005$ ]. (see Table 1.) Students in the VR

group perceived a higher learning quality than students in the Non VR group. The magnitude of the differences in the means was large (eta squared = 0.28). (see Table 1.) 28% of the variance in perceived learning was explained by the learning mode.

#### 4.4.3 Testing of $H_{03}$

The statistical results rejected the null hypothesis ( $p < 0.05$ ). There was a significant difference in perceived satisfaction for VR group ( $M = 4.02$ ,  $SD = 0.59$ ) and Non VR group [ $M = 3.21$ ,  $SD = 0.51$ ;  $t(360.633) = 14.210$ ,  $p < 0.0005$ ]. (see Table 1.) Students in the VR group were more satisfied with their learning experience than students in the Non VR group. The magnitude of the differences in the means was large (eta squared = 0.35). (see Table 1.) 35% of the variance in perceived satisfaction was explained by the learning mode.

Table 1: Mean scores, standard deviation (SD) and t-test of posttest, perceived learning and satisfaction of VR Group ( $N = 210$ ) and Non VR Group ( $N = 160$ ).

Variables	VR Group Mean (SD)	Non VR Group Mean (SD)	t	df	p-value	Eta squared
Posttest	65.51 (15.68)	60.56 (20.88)	2.506	284.863	0.013	0.02
Perceived Learning	3.94 (0.53)	3.30 (0.49)	11.844	368	0.000	0.28
Satisfaction	4.02 (0.59)	3.21 (0.51)	14.210	360.633	0.000	0.35

## 5. Discussion

The findings from this study supported the general hypothesis that VR-based learning environment positively affects the cognitive and affective domains of learners. The students performed better in the VR-based learning environment. This result was consistent with the findings of Chen [23] and Yang and Heh [24]. However, some research findings show no obvious benefits of using VR-based learning over traditional instruction on students' science achievement as in the study of Crosier, Cobb and Wilson [13]. Nevertheless, it was argued that only those science experiments that cover hands-on and minds-on activities and in which students could actively involved in the learning process can enhance the effect of computer assisted learning [25, 26]. These activities were integrated in the software used in this study where the students did the virtual dissection and enhanced their understanding by completing the lab report that scaffolded their understanding. It is possible that these helped students to grasp scientific facts and concepts more easily. Moreover, students controlled their own learning pace and actively involved in the learning activities because they made their own instructional decisions, experience and responsible for the consequences of those decisions. Thus, active and self-paced learning could be the partial cause as to why students' learning achievement was better in the VR-based learning environment. This is congruent with the principles of constructivism that advocate better learning results with active learning [27]. Consequently, the results of this study show that it is more powerful to support science learning with VR technology than with the traditional method.

The results also have a clear indication that VR technology was effective in boosting the students' affective behavior and the perception of their learning experience. The same

results were obtained in [28]. The higher perception in learning quality in the VR group indicates that VR was seen as an educational tool that could enhance learning and make learning more interesting and stimulating. The learning activities in the VR-based learning environment were perceived as meaningful and the learning experience with VR technology has made the students interested to learn more. These positive learning attitudes are imperative for successful learning achievement. Likewise, students in the VR group exhibited much higher satisfaction in learning. This could be due to the positive emotions generated during learning. It was shown that positive emotions experienced during learning improve learners' performance, satisfaction and perception towards learning [29]. Learning is more likely to occur with a positive state of emotion because learners make more constructive judgment as they interpret situations more positively [30]. The esthetic elements such as colours, layout and graphic illustrations of the VR learning material could be the partial cause of the positive effects on perceived learning quality and satisfaction. Hence, VR-based learning has provided an invaluable learning experience to students.

However, it is noted that small effect size was found for group differences in students' performance achievement. This indicates that the result should be interpreted more cautiously in a practical sense and further replication studies should be conducted.

## 6. Conclusions and Recommendations

The results of this study have supported some previous findings that VR could improve academic performance and affective quality. Moreover, the results have contributed to the limited findings on the effectiveness of VR against non VR teaching. In fact, the results have shown that the student-centred learning approach with VR was more effective. Students in the VR group not only benefited cognitively but also have more positive attitudes and in a more positive state of emotion while learning with VR. Though, VR should not be seen as a panacea that supports all kinds of learning situation, but its ability as an effective instruction intervention for teaching some things which are abstract and difficult to teach and learn should not be underestimated. Furthermore, the new generation in schools is a digital generation where computer has become part of everyday life. VR technology should therefore be considered as an alternative way of providing instruction within secondary-school classrooms. It is suggested that further research takes into account the human factor to investigate how learner characteristics interact with the features of VR-based learning environments in which the results would benefit individualized learning. Studies on how VR enhances the learning effectiveness are recommended. Further studies on the positive emotions experienced in VR based learning environments would help to explain the effects of VR on cognitive and affective domains.

## Acknowledgement

We thank Tactus Technologies, Inc., New York for granting us a license to use the V-Frog software for this research.

## References

- [1] Lee, E. A.-L., & Wong, K. W. (2008). A review of using virtual reality for learning. *Transactions on Edutainment 1*, 231-241.
- [2] Chen, C. J., Toh, S. C., & Wan, M. F. (2004). The theoretical framework for designing desktop virtual reality-based learning environment. *Journal of Interactive Learning Research*, 15(2), 147-167.
- [3] Strangman, N., & Hall, T. (2003). Virtual reality/simulations. Wakefield, MA: National Center on Accessing the General Curriculum. Retrieved May 9, 2006, from [http://www.cast.org/publications/ncac/ncac\\_vr.html](http://www.cast.org/publications/ncac/ncac_vr.html)

- [4] Dalgarno, B., Hedberg, J., & Harper, B. (2002). *The contribution of 3D environments to conceptual understanding*. Paper presented at the ASCILITE 2002, Auckland, New Zealand.
- [5] Youngblut, C. (1998). *Education uses of virtual reality technology* (No. IDA Document Report no. D2128). Alexandria, VA: Institute for Defense Analyses.
- [6] Roussou, M. (2004). Learning by doing and learning through play: An exploration of interactivity in virtual environments for children. *Computers in Entertainment*, 2(1), 10-23.
- [7] Song, K. S., & Lee, W. Y. (2002). A virtual reality application for geometry classes. *Journal of Computer Assisted Learning*, 18, 149-156.
- [8] Li, F. C., Angelier, J., Deffontaines, B., Hu, J. C., Hsu, S. H., Lee, C. H., et al. (2002). *A virtual reality application for distance learning of Taiwan stream erosion in Geosciences*. Paper presented at the International Conference on Computers in Education.
- [9] Aoki, H., Oman, C. M., Buckland, D. A., & Natapoff, A. Desktop-VR system for preflight 3D navigation training. *Acta Astronautica* (2007), doi:10.1016/j.actaastro.2007.11.001.
- [10] Barnett, M., Yamagatah-Lynch, L., Keating, T., Barab, S. A., & Hay, K. E. (2005). Using virtual reality computer models to support student understanding of astronomical concepts. *Journal of computers in Mathematics and Science Teaching*, 24(4), 333-356.
- [11] Crumpton, L. L., & Harden, E. L. (1997). Using virtual reality as a tool to enhance classroom instruction. *Computers & Industrial Engineering*, 33(1-2), 217-220.
- [12] Sanchez, A., Barreiro, J. M., & Maojo, V. (2000). Design of virtual reality systems for education: a cognitive approach. *Education and Information Technologies*, 5, 345-362.
- [13] Crosier, J. K., Cobb, S. V. G., & Wilson, J. R. (2000). Experimental comparison of virtual reality with traditional teaching methods for teaching radioactivity. *Education and Information Technologies*, 5(4), 329-343.
- [14] Chall, J. S. (2000). *The academic achievement challenge: what really works in the classroom?* New York: Guilford Press.
- [15] Chang, C.-Y. (2002). The impact of different forms of multimedia CAI on students' science achievement. *Innovations in Education and Teaching International*, 39(4), 280-288.
- [16] Hopkins, K. D. (1988) *Educational and Psychological Measurement and Evaluation*, 8th ed. USA: Allyn & Bacon.
- [17] Chou, S. W., & Liu, C. H. (2005). Learning effectiveness in a web-based virtual learning environment: A learner control perspective. *Journal of Computer Assisted Learning*, 21, 65-76.
- [18] Benbunan-Fich, R., & Hiltz, S. R. (2003). Mediators of the effectiveness of online courses. *IEEE Transactions On Professional Communication*, 46(4), 298-312.
- [19] Marks, R. B., Sibley, S. D., & Arbaugh, J. B. (2005). A structural equation model of predictors for effective online learning. *Journal of Management Education*, 29(4), 531-563.
- [20] Martens, R., Bastiaens, T., & Kirschner, P. A. (2007). New learning design in distance education: The impact on student perception and motivation. *Distance Education*, 28(1), 81-93.
- [21] Nunally, J. C. (1978). *Psychometric Theory* (2nd ed.). New York: McGraw Hill.
- [22] Cohen, J. W. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.
- [23] Chen, C. J., Toh, S. C., & Wan, M. F. (2005). Are learning styles relevant to virtual reality? *Journal of Research on Technology in Education*, 38(2), 123-141.
- [24] Yang, K.-Y., & Heh, J.-S. (2007). The impact of internet virtual physics laboratory instruction on the achievement in physics, science process skills and computer attitudes of 10th-grade students. *Journal of Science Education and Technology*, 16(5), 451-461.
- [25] Berger, C. F., Lu, C. R., Belzer, S. J., & Voss, B. (1994). Research on the uses of technology in science education. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 466-490). New York: Macmillan Publishing Company.
- [26] Chang, C. Y., & Barufaldi, J. (1999). The use of a problem solving based instructional model in initiating change in students' achievement and alternative frameworks. *International Journal of Science Education*, 21(4), 373-388.
- [27] Roblyer, M. D. (2003). *Integrating educational technology into teaching* (3rd ed.). NJ: Pearson Education.
- [28] Wekesa, E., Kiboss, J., & Ndigangu, M. (2006). Improving students' understanding and perception of cell theory in school biology using a computer-based instruction simulation program. *Journal of Educational Multimedia and Hypermedia*, 15(4), 397-410.
- [29] Um, E. R. (2008). *The effect of positive emotions on cognitive processes in multimedia-based learning*. Dissertation, New York University. Retrieved April 30, 2009, from ProQuest
- [30] Um, E., Song, H., & Plass, J. (2007). The effect of positive emotions on multimedia learning. In C. Montgomerie & J. Seale (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications*. Chesapeake, VA: AACE.